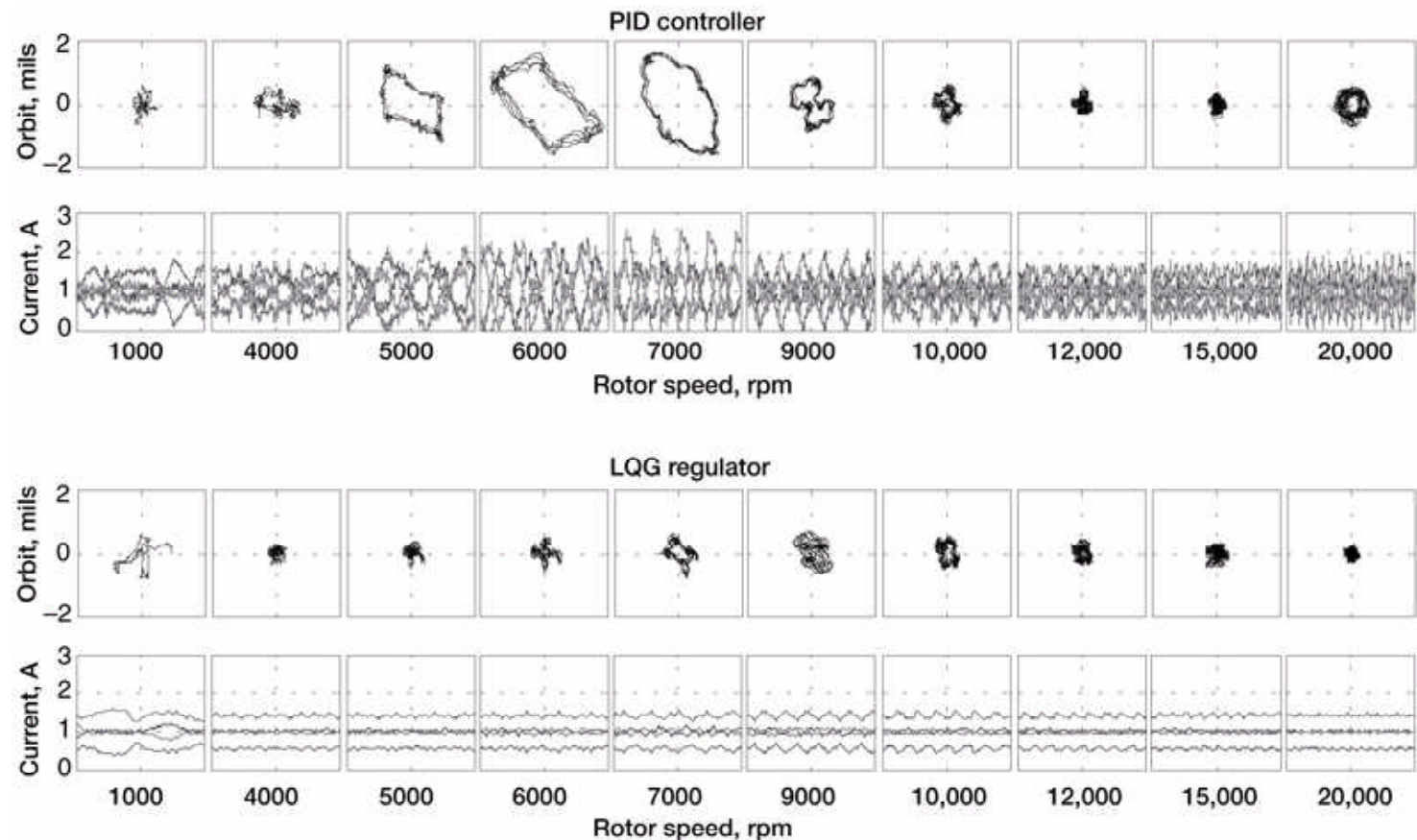


Linear-Quadratic-Gaussian Regulator Developed for a Magnetic Bearing

Linear-Quadratic-Gaussian (LQG) control is a modern state-space technique for designing optimal dynamic regulators. It enables us to trade off regulation performance and control effort, and to take into account process and measurement noise. The Structural Mechanics and Dynamics Branch at the NASA Glenn Research Center has developed an LQG control for a fault-tolerant magnetic bearing suspension rig to optimize system performance and to reduce the sensor and processing noise.

The LQG regulator consists of an optimal state-feedback gain and a Kalman state estimator. The first design step is to seek a state-feedback law that minimizes the cost function of regulation performance, which is measured by a quadratic performance criterion with user-specified weighting matrices, and to define the tradeoff between regulation performance and control effort. The next design step is to derive a state estimator using a Kalman filter because the optimal state feedback cannot be implemented without full state measurement. Since the Kalman filter is an optimal estimator when dealing with Gaussian white noise, it minimizes the asymptotic covariance of the estimation error.



Rotor orbit and corresponding control current of PID and LQG controllers over the rig's operating range.

A simple second-order dynamic model was derived through an experimental transfer function of the

plant model with an input of the control force and an output of the rotor displacement. An LQR with a Kalman filter was designed and implemented with the MATLAB/Simulink software. A real-time ANSI C code was generated, compiled, and downloaded to a dSPACE control system--an integrated control software and electronic control unit combination (MATLAB/Simulink software and ds1003/ds1004 alpha-combo, multiprocessor board). It was successfully demonstrated up to the rig's maximum achievable speed of 20,000 rpm. In comparison to a proportional-integral-derivative (PID) controller, which is one of the most popular classical controllers, this modern controller has the following benefits: (1) it significantly reduced the rotor orbits at critical modes, (2) it drastically improved power--saving more than 50 percent, and (3) it reduced measurement noise by more than 30 percent.

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